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JET DRYING OF SOUTHERN PINE AND DOUGLAS-FIR: EXPLORATORY STUDY

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ABSTRACT.—Southern pine and Douglas-fir boards, containing both heart- and sapwood and 1.75 inches thick, were jet dried at temperatures from 160 to 400°F and air velocities from 3,000 to 9,000 fmp. Jet drying was more effective for southern pine than for Douglas-fir.

OXFORD: 847.1—087. KEY WORDS: *Pseudotsuga taxifolia,* high temperature, shrinkage, drying defects, softwood.

Because of our success with high temperature jet drying several easy-to-dry hardwoods such as yellow-poplar and silver maple (Rosen 1977a), we felt that two of the most popular commercial softwoods, southern pine and Douglas-fir, could be jet dried. Previous work by the Australian CSIRO Forest Conversion Engineering Group (Anon. 1975) and Koch (1977) showed that green southern pine studs could be dried in less than 14 hours at temperatures to 300°F. On the other hand, reports of high-temperature drying of Douglas-fir have not been as promising. Salamon (1963) found that drying 2- by 8-inch Douglas-fir at temperatures to 225°F increased honeycomb and reduced strength more than conventional drying. So we decided to try jet drying southern pine and Douglas-fir lumber ourselves.

METHODS

Southern yellow pine and costal Douglas-fir boards, 40 inches long by 3¾ inches wide by 1¾ inches thick, were shipped to our Carbondale Laboratory wrapped in tightly sealed plastic packages.[1] Green specific gravity averaged 0.43 for both species. Immediately before a jet dryer run, three boards were trimmed to 30 inches by cutting 5 inches from each end. One-quarter-inch cross sections were cut from the trimmings of the boards for moisture content determination by oven drying. Boards were not endcoated except for six boards for the final two runs with Douglas-fir.

Boards were dried in a prototype jet dryer (Rosen 1977b) to approximately 12 percent moisture content at the conditions listed in tables 1 and 2. The drying period included one or two drying steps. Boards were periodically removed for 3 minutes from the jet dryer and weighed to the nearest 0.01 pound to establish drying curves for each board. Width and thickness to 0.001 inch were measured at four places along the length of each board before and after drying to determine volumetric

[1]*The southern yellow pine was cut from small logs; most of it included the pith and a small amount of heartwood. Douglas-fir contained both sapwood and heartwood.*

Table 1.—*Drying data for southern pine*[1]

Run	Drying			Conditioning[2]		Total time	Moisture content			Volumetric shrinkage[4]
	Temperature DB/WB[3]	Air velocity	Time	Temperature DB/WB[3]	Time		Initial	After drying	After conditioning	
	°F	fpm	Hours	°F	Hours		Percent			
1	400/180	3,000	2.0	200/190	3.0	5.0	118	14	14	5.7
2	300/180	3,000	3.5	200/190	3.0	6.5	127	21	18	5.1
3	300/180	6,000	3.3	200/190	6.0	9.3	111	10	11	5.4
4	300/180	9,000	3.0	200/190	3.0	6.0	105	9	10	5.8
5	240/160	3,000	11.4	195/185	3.0	14.4	111	9	10	5.3
6	220/180	3,000	14.3	200/190	8.5	22.8	89	12	12	4.8
[5]7	350/180 225/180	3,000 3,000	1.5 10.0	200/190	3.0	14.5	92	8	9	5.6

[1]Averages based on three boards.
[2]Air velocity for conditioning, 3,000 fpm for all runs.
[3]Dry bulb/wet bulb.
[4]Corrected to 12 percent moisture content.
[5]Drying done in two steps prior to conditioning.

Table 2.—*Drying data for Douglas-fir*[1]

Run	Drying		Conditioning		Total time	Moisture content			Volumetric shrinkage[3]
	temperature DB/WB[2]	Time	Temperature DB/WB	Time		Initial	After drying	After conditioning	
	°F	Hours	°F	Hours		Percent			
8	300/180 225/180	1.0 6.0	—	—	7.0	30	12	—	5.6
9	220/180	8.0	200/190	3.0	11.0	63	17	17	7.2
10	190/180 220/200	23.0	—	—	31.5	78	12	—	7.6
11	160/154 215/200	48.0 9.3	—	—	57.3	88	12	—	6.6
12	190/182 220/200	24.0 8.0	190/185	6.0	38.0	74	12	12	7.2
13	190/182 220/200	23.0 8.0	190/185	6.0	37.0	93	12	12	6.6
[4]14	190/182 220/200	23.0 8.0	—	—	31.0	109	11	—	6.3
[4]15	300/180	4.7	—	—	4.7	78	6	—	5.6

[1]Averages based on three boards, air velocity for all runs was 3,000 fpm.
[2]Dry bulb/wet bulb.
[3]Corrected to 12 percent moisture content.
[4]Endcoated with asphalt mastic.

shrinkage. After drying, all southern pine and several Douglas-fir boards were subjected to a high humidity conditioning period to reduce moisture content gradients and relieve internal stresses in the wood caused by the severe drying conditions. Boards were examined for surface darkening, collapse, honeycomb, and checking. One board from each southern pine run and two boards from each Douglas-fir run were crosscut into several sections to examine internal defects and to obtain 1-inch sections for moisture content determination.

The uncut dried boards were placed in a constant temperature and humidity room until an equilibrium moisture content of 6 percent was reached. Boards were then weighed and moisture contents of the boards during drying were calculated.

RESULTS AND DISCUSSION

Figure 1 is typical of the moisture-content/time curves for boards dried under constant air velocity and wet bulb temperature. The rate of drying slowly dropped as the drying proceeded. Surface darkening was observed on all boards dried above 212°F. High drying temperatures and low final moisture contents produced the most discoloration: as moisture content dropped below 10 percent, the board surface darkened rapidly at temperatures above 250°F.

SOUTHERN PINE

Southern pine withstood drying temperatures up to 400°F with minimal degrade. Except for slight end checking and surface checks around knots, the quality of the boards dried at all conditions was good. A previous study with 4/4 silver maple found increases in air velocity above 3,000 fpm did not reduce drying time (Rosen 1977a). But, for southern pine increasing in air velocity reduced drying time (compare the drying times of Runs 2, 3, and 4 in table 1).

Although southern pine can be dried in a few hours at temperatures higher than 300°F,

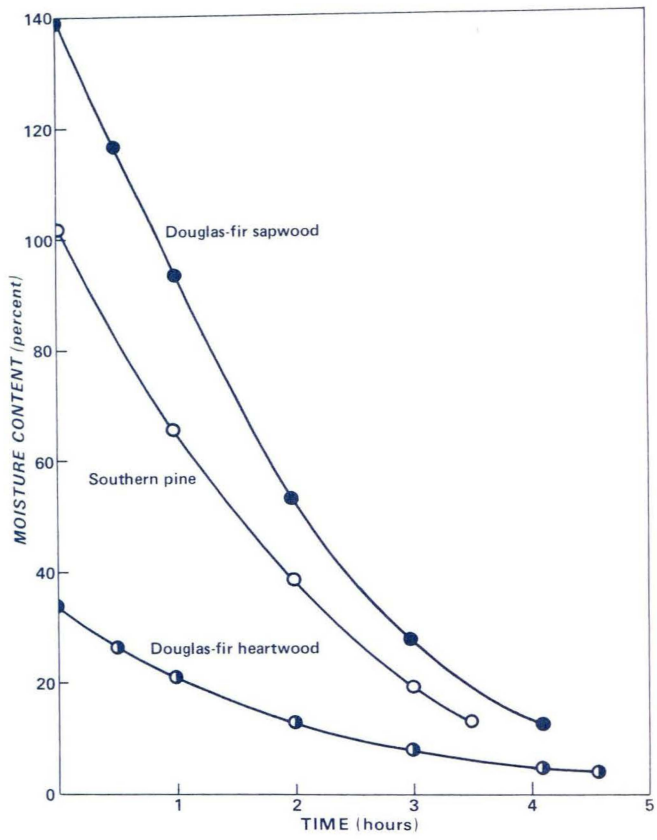

Figure 1.—*Moisture content versus time for 1.75-inch-thick southern pine (Run 2 conditioning period not shown) and Douglas-fir (Run 15) jet dried at 300°F dry bulb, 180°F wet bulb and 3,000 fpm air velocity.*

the possibility of overdrying the lumber and the wide range of final moisture contents of the boards are undesirable. The mixed high and moderate temperature schedule of Run 7 (table 1) would reduce the problems involved with a straight high temperature schedule.

DOUGLAS-FIR

Rapid drying of coastal Douglas-fir is confounded by the wide range of green moisture contents 28 to 146 percent found in the wood. Heartwood boards were drier than sapwood. When drying Douglas-fir at a single high temperature, the heartwood was overdried and the sapwood underdried (fig. 1). Several combinations of high and low temperatures, with and without conditioning steps, were attempted (table 2), but honeycomb and end

checking persisted. Honeycomb was more severe in the boards dried at high temperature only than in those dried at low temperature followed by high temperature (fig. 2). End-coatings did not reduce end checks or honeycomb. Jet drying 1.75-inch-thick Douglas-fir at a constant high temperature is not recommended. A mixed low and high temperature schedule can dry the wood in less than 31 hours, provided some honeycomb of the wood is acceptable.

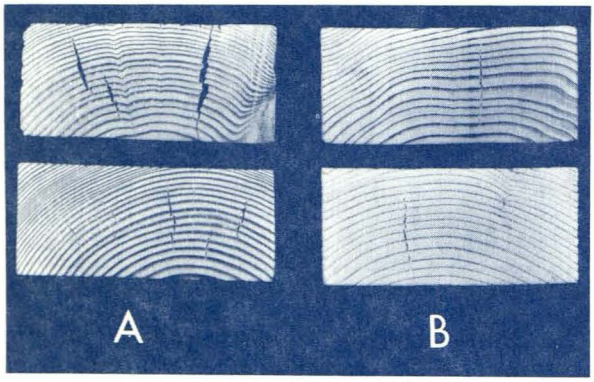

Figure 2.—*Typical honeycomb in Douglas-fir jet dried by a high temperature schedule (A-Run 8) and a low followed by a high temperature schedule (B-Run 11).*

CONCLUSION

Our results indicate that southern pine can be high temperature jet dried in less than 15 hours. The most effective schedule over the range of conditions studied was a short exposure of the wood to very high temperature (above 300°F) followed by a moderately high temperature (220 to 240°F), and finally a high humidity conditioning period. The process could be adapted to a continuous kiln similar to that described by Koch (1977), whereby wood is carried through three sections of a kiln set for the respective conditions stated above. High temperature jet drying of Douglas-fir produced defects in the wood, although drying at low temperature and then increasing to high temperature near the end of drying minimized these defects.

LITERATURE CITED

Anonymous. 1975. Australians develop fast dry kiln. World Wood 16(3):30.

Koch, P. 1977. Continuous tunnel kiln direct-fired with bark to dry 1.75-inch southern pine in 24 hours. For. Prod. J. 27(5): 39-47.

Rosen, Howard N. 1977a. Drying of hardwoods with impinging jets. Paper presented at the Wood Drying Technical Session of the IUFRO Meeting, Merida, Venezuela, October 3, 1977.

Rosen, Howard N. 1977b. A prototype jet impingement dryer. For. Prod. J. 27(10):34-37.

Salamon, M. 1963. Quality and strength properties of Douglas-fir dried at high temperatures. For. Prod. J. 13(8):339-344.

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